April 1975

B75-10009

NASA TECH BRIEF

Lewis Research Center

Design Criteria Monograph on Axial-Flow Turbines

A design criteria monograph has been published which is a summary and a systematic ordering of the large and loosely organized body of current techniques and practices for the successful design of liquid rocket engine turbines.

This monograph was written to organize and present, for effective use in design, the significant experience and knowledge accumulated by NASA in development and operational programs. It reviews and assesses current design practices, and from them establishes firm guidance for achieving greater consistency in design, increased reliability in the end product, and greater efficiency in the design effort.

The attainment of turbine predicted performance will be more critical in the next-generation rocket engines than in past engines because more horsepower will be developed per unit turbine size and because a closer interdependence will exist among turbine efficiency, engine specific impulse, and chamber pressure. This monograph provides guidelines for predicting turbine performance, sizing gas-path elements, and avoiding problems associated with mechanical design and development. Typical problems and solutions in past rocket engine programs include the following: changes to the turbine design pressure ratio affected gas-path energy distribution, and the turbine nozzles and blading had to be modified or redesigned; differential expansion and component cracking at weld joints during operation required modification of turbine casing and manifold design; blading failed during turbine operation, and changes were made to blade/disk attachments and to blade/shroud configurations in order to reduce stress levels and stress concentrations; and forged rotor disks failed because of poor material ductility, a condition corrected by increasing the solution-heat-treat temperature specified for the disk forgings.

The material in the monograph is organized along the lines of the design and development effort necessary to produce a turbine that satisfies the requirements imposed on it. A new turbine design is initiated with preliminary studies that establish design state conditions, turbine size, and performance estimates. Operational requirements of the oxidizer and fuel pumps and of the propellant feed system are used to establish turbine design horsepower, speed, pressure ratios, working-fluid properties, and operational characteristics. This preliminary turbine analysis is supplemented with layout studies of gas-path elements and candidate turbine configurations. The in-depth aerodynamic and detailed mechanical design of turbine hardware is subsequently accomplished during the turbomachinery development program.

The monograph comprises two major sections: State of the Art, and Design Criteria and Recommended Practices. References complement the text.

The State of the Art section reviews and discusses the total design problem and identifies the design elements that are involved in successful design. The Design Criteria state clearly and briefly each rule, guide, limitation, or standard that must be imposed on each essential design element to assure successful design; the Recommended Practices set forth the best available procedures for satisfying the Design Criteria.

Both major sections are divided into seven subject categories: Preliminary Design Analysis (pressure ratios, flowrates, and performance; fluid properties; velocity ratios; staging); Aerothermodynamic Point Design (energy balance, velocity and pressure distribution, and power; partial-admission turbine; stage reaction; maifold sizing); Nozzle, Vane, and Blade Geometry (leading and trailing edges; pressure and suction surfaces; etc.); Mechanical Design and Structural Analysis (blading; nozzle; stator and rotor; casing, manifold, and diaphragm); Integration and Assembly (rotordynamics, bearings and seals, exhaust ducts, problem areas); Turbine Materials; Provisions for Instrumentation.

This thorough review of design criteria and practices relating to axial-flow turbines should be of interest to manufacturers and users of power drives, turbine drives, and general rotary equipment.

(continued overleaf)

Notes:

1. This monograph has been published as the following report:

   NASA SP-8110 (N74-34245), Liquid Rocket Engine Turbines

   Copies may be obtained at cost from:

   Aerospace Research Applications Center
   Indiana University
   400 East Seventh Street
   Bloomington, Indiana 47401
   Telephone: 812-337-7833
   Reference: B75-10009

2. Specific technical questions may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B75-10009

Source: Lewis Research Center
(LEW-12376)